TOUCH AND KINESTHESIS

by

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This review includes seventy articles which may be listed under the joint title of touch and kinesthesis. Most of them were published in the years 1930 and 1931. A number of articles which bear an earlier date of publication are included because they were not yet available when the writer submitted the last review upon this topic (this JOURNAL, 1930, 27, 298–317). These studies are classified under fifteen sub-topics (*vide infra*), according to the nature of their content or results, or their setting in this increasingly broadening field.

Excitation and discharge of sensory impulses.—Adrian (1) dealt with the problem of excitation in mechanically activated sense organs, designating the conditions which are responsible for the discharge of impulses over the nerves during excitation in the receptor. The available evidence seemed to him to indicate that excitation is to be correlated with definite changes in the surface layer of the receptor. The surface layer was observed to become thinner during stimulation, establishing a basis for the discharge of sensory impulses in a condition of altered permeability and of depolarization. The frequencies of discharge were found to vary with the conditions and amount of stimulation.

Fessard (24) set out to study the temporal relationships in brief cutaneous stimulations. He developed a technique (25) by which the finger was stimulated with the edge of the mirror of a Du Bois oscillograph. The deviations made by the mirror during contact were photographically registered, giving an accurate record of the pressure and its exact progress in time. By comparing this record with that of the course of the free mirror, he was able to determine the energy which was delivered to the tissues during contact. Stimulating the cutaneous receptors in this mechanical way, Fessard (25) found the liminal energy to be .01 *erg,* a value much lower than von Frey reported. He expressed the belief that the liminal energy for direct stimulation of unprotected receptors, such as those at the base of the hair, may be found to be as low as .001 *erg.* He also (26) determined that the latent time for mechanical stimulation of the

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27. Snyder, L. H., Inherited Taste Deficiency. *Science*, 1931, **74**, 151–152.
28. Valentine, J. M., The Olfactory Sense of the Adult Meal-Worm Beetle Tenebrio Molitor (Linn). *J. Exper. Zool.*, 1931, **58**, 165–228.
29. Wells, F. L., Reaction-Times to Affects Accompanying Smell Stimuli. *Amer. J. Psychol.*, 1929, **41**, 83–86.
30. Wirth, W., Untersuchungen über Reizschwellenwerte von Geruchsstoffen bei Insekten. *Biol. Zentralbl.*, 1928, **48**, 567–576.
31. Young, P. T., Studies in Affective Psychology. VIII. The Scale of Values Method. *Amer. J. Psychol.*, 1930, **42**, 17–27.

skin varied with intensity of stimulation. This relationship was not so clearly expressed as in Piéron's work, owing to the fact that the edge of the mirror of the oscillograph depressed the skin at a more rapid rate. He also ascertained that the reaction time for repeated (1000 per sec.) stimulation was shorter than for simple stimulation at any given intensity, excepting at high intensities where these reaction times were the same.

When the biceps was stimulated at its motor point, Renqvist and Mali (56) found the chronaxie for sensation of tension to be greater than that for contraction, and the rheobase value for sensation of tension to be less than that for contraction. But when the electrodes were applied to the body of the muscle, the chronaxie and rheobase values for sensation of tension and for contraction were the same, because in this case sensation of tension resulted only when contraction was induced. The chronaxie of superficial sensation, like a creeping on the skin, was determined to be greater than either of the other chronaxie values. Rothe (60) developed a technique by which he was able to measure the chronaxie of the *m. flexor Carpi ulnaris* in children prematurely born and in those born at normal time. He found the chronaxie to be higher in the prematurely born, but the degree of discrepancy became smaller with increasing age.

Bronk (8) stimulated the receptors in excised muscle by prolonged and interrupted loadings and stretchings, taking records of the afferent impulses discharged in each case. The muscle receptors seemed to adapt quickly and completely to interrupted short stretching stimulations; no change in the frequency of impulses was observable even after one thousand separate stimulations each of which was followed by only one second of rest. Prolonged stimulation, however, resulted in decreased frequencies of impulses, presumably because fewer and fewer receptors discharged as time progressed during the period of stimulation. The effect of fatigue, indicated by a diminution in the number of impulses discharged, was observed in the sustained stimulation of a single receptor. Keller and Loeser (44) recorded the action currents which were released when tension was applied to the gastrocnemius muscle of the frog. The results indicated that the number of impulses discharged was directly proportional to the amount of tension, and that at a given degree of tension the number of discharges recorded in repeated trials was approximately constant.

Griesbach (33) expounded the theory of a mutual relationship between irritation (*Erregung*) and fatigue in connection with meas-

urements of esthesiometric thresholds. The size of the threshold was alleged to differ with variations in the relative ascendancy of irritation or fatigue. The left hemisphere of the cerebrum was assumed to be chiefly concerned with mental work, and the right with bodily work. Consequently, irritation and fatigue resulting from work would be differently distributed in the two hemispheres. According as either factor prevailed over the other, the thresholds on the opposite side of the body were alleged to vary.

Temperature sense.—Weber believed that a change in temperature constituted the specific stimulus for the arousal of temperature sensation. Von Frey (29) has pointed out that Weber recorded an observation himself which apparently failed to meet the prescription of his own theory. He reported that a cooled key, applied to the forehead, aroused a cold sensation not only during the presentation but for some twenty minutes following its removal. Von Frey has explained that this is only an apparent exception to Weber's theory. Upon removal of the key, heat conduction proceeds from the surrounding area to that which had been cooled by the key, and provides a condition of temperature change adequate to excite the cold organs in the adjacent, previously unstimulated area. Cold is aroused instead of warm because of the less sparse distribution of cold as compared with warm organs.

In order to avoid contact and deformation of the skin in the stimulation of heat, Sullivan and Verda (66) stimulated the skin at two separate points with independent systems of cold and warm air. They were able to arouse heat when the two stimulators were applied at separations within the compass of 1 and 14 cm. The experience was localized at a point midway between the stimulators, and was described as being more extended than either of the separate components. Aside from references to such sensory qualities as tingle, sharpness, and prickling, the characterizations did not include descriptions of pressure. By removing one stimulator after heat had been aroused, it was discovered that cold was the more salient component, the one which gave heat its tingling and stinging character. Using a heat grill as the instrument of stimulation, Ferrall and Dallenbach (22) analyzed burning heat into cold, warm and pain. Then by using combinations of cold and warm, respectively between 9° and 20°C. and 38° and 44°C., and by exciting pain electrically, they effected a satisfactory synthesis of the experience. The investigators failed to arrive at a decision in regard to the ultimate or inherent nature of burning heat; whether it is a "complex" or mixed sensa-

tion including the several component elements, or a specific experience lying on the pressure-prick-pain continuum. Lowenstein and Dallenbach (48) determined the critical temperature for heat and burning heat by requiring their subjects to characterize the experiences which followed stimulations at every degree within the bounds of 40 and 51°C. The critical temperatures for heat varied from 40 to 46°C, with an average of 42.87 ± 1.07; those for burning or painful heat varied from 43 to 51°C., with an average of 47.09 ± 1.29. These results were interpreted as signifying that burning heat is an integration of heat and pain.

Drury and Dallenbach (14) undertook to find out how frequently during a sixty-minute period a cold organ may be stimulated without failing to respond maximally in consequence of fatigue. Cold spots were marked and stimulated at intervals of 5, 15, 30, 60, 180 and 300 sec. The sensations aroused were described in reference to a four-point scale—intense, moderate, mild and weak. The receptors responded to stimulation at all intervals in a large percentage of cases. No interval seemed to be distinctly more favorable, although the three longer ones amassed a larger number of responses than the three shorter intervals. The authors drew the cautiously discreet general conclusion that the same spot may be stimulated, without any danger of alteration in response as a consequence of fatigue, at least every fifteen minutes or five times per hour.

Bazett, McGlone and Brocklehurst (5) introduced light thermocouples into the skin near warm and cold spots and secured results in regard to latent time and rate of penetration. By correlating these results, they established that the cold receptors are located in the skin at a depth of .15 ± .1 mm., and the warm organs at a depth of .6 ± .2 mm. Accordingly, the warm receptors cannot lie in the sub-dermal tissues, but the Krause end-bulb may be the organ for cold. Bazett and McGlone (4) found that the latency for the sensation of heat was longer than that for either warmth or cold. The curves for latency of sensation were more complicated for warm than for cold stimulation. The authors asserted that this difference in respect to the nature of the latency curves for cold and warm sensation should be attributed to the fact that a warm stimulus usually arouses cold paradoxically, but that it is extremely rare for a cold stimulus to effect a paradoxical stimulation of warm receptors.

Laignel-Lavastine and Odinet (45) reported the case of a syphilitic who was unable to perceive degrees of thermal sensation on the left lower limb, all degrees of temperature being described as

tepid. In this same region, pressure sensitivity appeared to be normal, but that to prick was slightly diminished. After treatment, sensitivity to pain became normal and that to degrees of temperature began to show improvement. This apparent disjunction in cutaneous sensation was taken to denote that the impulses which aroused the several cutaneous qualities were transmitted over different nervous pathways.

Schlosberg and Carmichael (61) constructed a simple heat grill with two removable comb-like elements of copper or nails set in a wooden block. After warming one of the elements and cooling the other one, they were fitted together in position for the subject to place the hand or arm on the intermeshed elements. Barry and Bousfield (3) built a simple heat grill on the hot plate principle. It consisted of two wooden plates with two systems of screws, arranged in alternate or checkerboard series.

Dallenbach (12) developed a method for tattooing the skin so as to insure the possibility of stimulating the same spots at succeeding sittings. It consisted in the use of a capillary tube, the end of which was twisted on the spot until it had cut into the cutis.

Tickle.—Relying largely upon the writings of Ebbinghaus and Titchener, Hatano (35) set forth the specific qualities of the sensation of tickle, discussed its relationship to other cutaneous qualities and to instinct, and treated the topic of its localizability.

Pain.—Piéron (52) ascertained that the rate of propagation of impulses over a cutaneous nerve varied with the type of stimulation. The rates given in meters per second were: for burning 4.5, for pinching 12, for pricking 16, and for touching the skin 40. These results were related to the finding of Gasser and Erlanger, and others, that stimulation is attended by impulses traveling at different rates over the nerve.

Piéron (53) discovered that the reaction times for two different kinds of stimulation—burning and pricking—were not the same in certain parts of the body. In the head region, the reaction time for burning was found to be shorter than that for pricking; on the foot the reverse was true; and on the hand, both reaction times were the same. He related these results to the epicritic-protopathic theory of Head.

Previously, Naunyn, and Gad and Goldscheider, reported that a kind of summation effect appeared when the same point on the skin was repeatedly stimulated; thus, a weak stimulation eventually seemed to be stronger, or a non-painful one aroused pain. In these experi-

ments, the same spot was stimulated in successive trials. By stimulating two pain spots, lying within the space limen, at different intensities, and requiring the subject to make comparative judgments of intensity, Schriever (62) endeavored to avoid the possibility that repeated stimulations at the same spot might have led to injury in the previous investigations and thus to a change in conditions to account for the alleged summation effect. Under these conditions, Schriever failed to find any evidence of a summation effect, that is to say, there was no apparent change in intensity as a result of continued stimulations.

Cordotomy is a surgical method which is used to relieve patients who suffer from certain types of excessive pain. Stookey (64) was able to eliminate pain by this method without affecting thermal and tactual sensitivity in the region. He brought forward evidence to indicate that the impulses which occasioned pain were transmitted over fibers in the lateral spino-thalamic tract, while those which gave rise to temperature were dispatched over a tract more ventrally located, probably the ventral spino-thalamic tract.

Willemse (70) reported that Störring did not favor the view of von Frey in regard to the status of pain. Grouping pain with organic sensations, Störring took a position midway between Ziehen, who identified pain and unpleasantness, and von Frey, who listed pain as a specific sensation. Dumas (15) has just classified pain as a unique sensation, indicating points of distinction between it and unpleasantness. Burridge (9) has recently discussed pain—toothache in particular—in connection with his theory of excitation, according to which experience is said to arise from an interaction between calcium salts and colloids.

Sensitivity in the mouth.—Hirsch and Schriever (36) explored the tongue, the larynx, and the walls of the throat to determine the nature of sensitivity. Behind the circumvallate arch, the tongue was found to be insensitive to pressure. Pressure sensation was limited to the regions supplied by the trigeminal and glossopharyngeal nerves. Excepting on the tip of the tongue and in the neighborhood of veins where a condition of hypersensitivity prevailed, pressure sensation on the tongue was very similar to that on the skin. Pain was elicited in all parts of the tongue and throat, having a high threshold anterior to the circumvallate arch. Cold was most acute at two points, on the tip of the tongue and on the larynx, especially at the epiglottis. There was diminished sensitivity to cold at all other points. Warmth was well developed on the tip of the tongue and on the forward

edges; elsewhere there was hyposensitivity to warmth, and posterior to the circumvallate arch the tongue and throat were found to be insensitive to warmth. These results were related to cutaneous theory in such a way as to support the doctrine of specific energy of nerves.

Touch localization.—Although all of his subjects made improvement with practice in regard to accuracy of cutaneous localization, Renshaw (57) found that children between eight and eleven years made more rapid improvement than subjects of eighteen or more years of age. With vision excluded, the average error of localization for adult subjects was found to be larger than that for children, but when the subject was allowed to open the eyes after stimulation—during the act of localization—the magnitude of the average error was larger for children than for adult subjects. Renshaw concluded that ability to localize is essentially a matter of learning; and that children depend at first primarily upon touch and kinesthesis but with increasing age bring vision more and more into play in the localizing act. In order to test the hypothesis that adults rely relatively more than children upon visualization and less upon touch and kinesthesis in the act of localizing, Renshaw, Wherry and Newlin (58) compared the results of localizations of congenitally blind adults and children with those of visually capable adults and children. In the tactual-kinesthetic localizations, the average errors of blind adults were smaller than those of blind children, those of visually normal children were smaller than those of normal adults, and those of normal children were smaller than those of blind children. Using groups of children of different ages as subjects, Dunford (16) found gradual improvement in regard to accuracy of localization with increasing age, excepting in the cases of his two oldest age groups, eleven and fifteen, for which the average errors of localization were larger than for children at earlier ages. The results were thought to support, in general, the genetic theory; nevertheless, the fact that subjects at lower ages made highly and uniformly accurate localizations at the first sitting was designated as a point in defense of the modified nativist theory. In his medical practice, Söderbergh (63) had observed that his patients made confusions in regard to which toe had been touched. In experimental trials, he discovered that the correct digit was consistently indicated when the great or little toe was touched, but that confusion in regard to localization tended to be the rule in the case of the three inner toes.

Boring (7) raised the question as to why the magnitude for two-

point limen determinations should be several times larger than the average error of localization in the same region. Wundt and Head were cited as defending the view that two-point discrimination and localization represent different cutaneous functions. Boring took the position, however, that these two functions may have their basis in a single physiological function, and that the discrepancy in the results which have appeared from Weber down to the present are to be explained in terms of differences in training and in conditions of experimentation in the two specific situations.

Drugs and sensitivity.—Hoefer (38) gave subcutaneous injections of different concentrations of morphine, or its derivatives, regularly for a period of several weeks and made tests in regard to dermal sensitivity. Temperature sensitivity was not at all influenced by the injections. The curves for pressure sensitivity showed a sharp drop after injection, with subsequent sharp recovery. The effect was at all times "acute" in the case of pressure, that is to say, there was no indication of a tendency to adaptation to the effect after a period of continued use of the drug. Increase in concentration of the dose resulted in sharper changes in the pressure curve. The curves for pain sensitivity resembled those for pressure in the early stages, but after a period of regular daily injections the pain receptors manifested adaptation to the drug in that diminution in sensitivity did not follow the injections.

Willcutts (69) used a local anesthetic for abdominal operations, and reported the patient's account of sensations during application of anesthetic, making of incision, delivery of appendix to wound, and closure of wound. Most of the sensations were non-painful, but fleeting pain and nausea, in neither case severe, were occasioned by the manipulation of parts.

Size-weight illusion.—Ciampi (10) secured results which indicate that mental deficiency cannot be diagnosed accurately, as earlier writers alleged, in terms of the *signe de Demoor* or insusceptibility to the size-weight illusion. Previous investigators who reported the absence of this illusion in the subnormal are said to have failed in completely eliminating the influence of suggestion and in maintaining uniform conditions in their experiments. Rey (59) compared the results of normal and subnormal children at different age levels in regard to degree of prevalence of the size-weight illusion. It was found to be less pronounced, or absent, in the younger normal and in the subnormal groups, and in several cases the reverse of the illusion was demonstrated. He reached the conclusion that a certain

level of mental development was necessary to the occurrence of the illusion.

Usnadze (68) designated the size-weight illusion the "pressure" illusion. He also demonstrated a "volume" illusion in which case two objects of the same size but of varying weight appeared to differ in respect to size. Usnadze attempted to determine the bases of these illusory judgments. The size-weight illusion had been explained by Müller and Schumann in terms of secondary impressions which were thought to arise during the lifting of the weights and to have a decided effect upon the judgment. Claparède thought this illusion had its basis in different complexes of strain sensations which were aroused in the joints when objects varying in size but not in weight were lifted. Usnadze pointed out that neither of these theories proved satisfactory to account for the fact that the illusion continued to prevail when there was no lifting, that is to say, when the weights were applied to the skin. He explained the illusion on the ground that an attitude is built up in reference to that factor in respect to which the two objects differ. In the case of the "pressure" illusion, with objects varying in size but not in weight, the attitude is based on the character of size; in the "volume" illusion, with objects varying in weight but not in size, it is founded on the item of weight. Thus, the perception of smaller-larger difference influences the judgment of weight in the "pressure" illusion, and the perception of heavier-lighter difference affects the judgment of size in the "volume" illusion.

Perception of space.—Förster (27) called attention to the fact that in the act of mirror drawing the subject is required to disestablish, and to reorganize in a different manner, the elements which had previously been organized into his conception of space. In this learning situation, it was shown (a) that the motor acts were guided primarily by vision, not by touch; (b) that trial and error movements were made until it was visually perceived that one of them started in the right direction; and (c) that the performance was unsuccessful with the eyes closed. Experiments in which visual and tactual apprehension of form and size were compared led Bonaventura (6) to the conclusion that vision represented the better means to the realization of space. The non-visual or tactual perceptions were usually less accurate, and as a matter of fact vision was not entirely excluded by blindfolding the subject.

Katz (43) made a comparative study of children, adult and blind persons with regard to ability to identify or name a series of objects

which were presented tactually, or non-visually, and to designate the material substance out of which each was made. With regard to naming the objects, children rendered much quicker judgments than adults and tended not to depend upon secondary criteria. Adults were superior in designating the kind of material. The reaction times for naming were slightly quicker in the case of the blind than in that of children, but the former were most handicapped in the matter of indicating the kind of material. Merry (49) reported a study in which blind children were tested with regard to ability to apprehend embossed pictures of familiar objects. These children were greatly handicapped, the degree depending on the presence or absence of outstanding features, conceptions of perspective, and familiarity of objects.

Lamarque (46) ascertained that blind subjects depended upon cutaneous as well as auditory impressions in making judgments in regard to the proximity of an object, such as a wall. With hearing excluded, these subjects relied upon the impact of air waves on the forehead and temples. Lamarque found no evidence to support the view of the layman, that the blind have superior sensory acuity in hearing and touch.

Using both normal and pathological subjects, Renqvist (55) discovered that temporal judgments were relatively more independent and fundamental than spatial judgments in perceptions of movement. He concluded that spatial judgments have their neurological basis in the cortex, but that judgments of time probably are subcortical integrations.

Gault (31) gave dual (visual and tactual) stimulation in the presentation of speech sounds to deaf subjects through the instrumental means of his "teletactor." The subject was found to learn more rapidly by dual than by unimodal (visual) presentation.

Craig (11) determined that an unfilled extent, apprehended cutaneously, was judged to be 18 per cent longer than a filled extent of the same magnitude, and 13 per cent longer than a partially filled extent. By comparing the unfilled extent with a variable of the same kind and size, a time error amounting to 2 per cent was discovered. It was inferred, therefore, that the two figures just given are exaggerated by that amount.

Perception of movement.—Mukherjee (50) set out to test the law of Vierordt which stated that the magnitude of the space limen at any point on the limb would be found to vary inversely with the distance from the axis of rotation. He made determinations at

different points on the volar surface of the right arm, and found, in accord with the law, that the limen for the fingertip was smallest and that for the tip of the middle finger was smallest of all. The law was confirmed in general, except that since there was improved sensitivity in the neighborhood of joints, and especially around the shoulder, as compared with interjoint areas, the results did not seem to validate the law without reservation.

Renqvist (55) was concerned with the perception of bodily movement, and indicated the comparative inadequacy of pathological subjects, such as those blind from birth or with certain brain traumas. Leriche (47) found that the articular ligaments were supplied with nerves adequately to provide for sensitivity in the peri-articular regions. Under normal conditions, stimulation failed to arouse sensation, but in cases of altered constitution of the blood, especially in cases of excessive calcium, extreme pain was reported to occur.

Lifted weights.—Turner (67) found that previous stimulation had a modifying influence on the psychophysical judgment. In his first experiment, two distinctly heavier or distinctly lighter weights were compared just before each comparison in his regular series of weights. In this case the retentive trace of the preceding comparison was effective in shifting the judgments in the following or regular series in the direction of the preceding weight. More heavier judgments appeared in the comparisons in the regular series when the preceding pair of weights were distinctly heavier, and more lighter judgments were made after preceding comparisons of two distinctly lighter weights. In his second experiment, Turner presented three weights, the last two of which belonged to his regular series. The subject was required to compare the second with the first weight before he compared the third with the second. Here the results showed a tendency in the second of two successive judgments to a reversal of the first judgment, more lighter judgments following previous heavier ones and *vice versa*. Turner did not think that his results supported the configuration doctrine.

Guilford and Park (34) interpolated a 100 or a 400 grm. weight between each presentation of a 200 grm. standard and one of its variables in a lifted weight experiment. He found that the resulting difference limen was enlarged and that there was a shift in the psychological values of the variable weights relative to the standard. The results were interpreted as favoring the theory of configuration, in that the comparative judgment was made in terms of an alteration

in potential occasioned by lifting the interpolated weight, which changed the dynamic neurological processes underlying the judgment.

Gahagan (30) compared the precision of judgments in experiments with lifted weights (a) when the standard was followed by its variable, (b) when the standard was followed by two variables with both of which it was compared, and (c) when the standard was followed by seven variables with each of which it was compared. Although the subject is said to have retained no clear impression of the standard in terms of which to make the seven comparisons in the third series, the limen and precision values are of the same order as those in the other series. Therefore, although made in terms of an absolute judgment, they show the same degree of precision as regular comparative judgments. Fernberger (20) found that normal curves of the psychometric function resulted in a lifted weight experiment in which no standard was used, but in which the subject was required to evaluate each weight in terms of an absolute judgment. However, precision of judgment was lower and the interval of uncertainty much greater in this experiment than in the regular series in which a standard was used.

Using four different types of instruction for prescribing and defining the categories of judgment, Fernberger (19) secured results which revealed that the effect of practice tended to diminish "equal" and "guess" judgments. In this study as well as in another (21), he emphasized the importance of a stable attitude in psychophysical work.

Hoagland (37) called attention to the fact that the logarithmic relation known as the Weber-Fechner law has not been demonstrated except in the mid-regions of intensity, and even there it has been demonstrated with no high degree of precision. Referring to experiments in vision, touch and kinesthesis, he attempted to show that this alleged logarithmic relationship is probably a function of the *all or none* law. Thus, with progressive increments in intensity of stimulation, more and more receptor cells are excited.

Ponzo (54) called attention to the fact that there is a psychological difference between the same amount of gradual increase and of gradual decrease in the perception of weight at any point on an intensive continuum, and that this fact should be taken into account in all psychophysical work having to do with the perception of weight.

The sense of vibration.—Petzoldt (51) performed experiments having to do with localization, threshold values, masking and apparent movement of sensations of vibration. If both hands were placed on

a rod which was connected with a vibrator, the direction of the source of stimulation could be determined in terms of differential stimulation in the two hands. With the arms crossed, confusions in regard to localization were frequent. When one hand only was placed on the rod, more intense stimulation was required for consistent judgments in regard to the direction of the source of stimulation. Localizations by the feet were about as accurate as those by the hands. The threshold values of the hand and foot were found to be approximately the same. With regard to masking, Petzoldt found that vibration was perceived only in that one of the hands which was more intensively stimulated. In view of the fact that the weaker stimulation could be felt when the hand which was being stimulated more intensively was withdrawn, he concluded that masking took place in the cortex. Apparent movement of vibratory sensations was demonstrated in two ways: (a) by withdrawing the hand which was stimulated at higher intensity, and (b) by altering the intensity ratio so as to make the more intense stimulation shift to the hand which had just been undergoing weaker vibratory stimulation.

Von Frey (28) expressed the opinion that Katz and Noldt (*Zsch. f. Biol.*, 1927, 86, 525–526) did not succeed, as they alleged, in demonstrating the independence of vibratory sensations as against pressure sensations by stimulating the former at such low energy that pressure was not excited. Von Frey has pointed out that they worked in a very sensitive part of the skin—the tip of the finger—and he has calculated that the energy of their stimulus was supraliminal for pressure. He also took issue with them in regard to their assertion that movement is a specific character of sensations of vibration, and pointed out that vibration can be occasioned by the stimulation of a single receptor.

One of a series of lectures by Katz (42), entitled "The Vibratory Sense" (pp. 90–104), is related to this topic. The treatment is general, setting forth chiefly the points of distinction between the sense of vibration and that of pressure.

Kampik (41) compared deaf and hearing subjects in regard to ability to perceive vibrations. Through vibratory sensations, deaf subjects were able to distinguish between tones and noises at once, but hearing subjects were not able to do so until after a period of training. Within a limited region, pitches as close together as the semitone could be discriminated. The upper threshold was determined at about 1,300 and the lower at 16 vibrations per sec. Mate-

rials were distinguished and verbal characterizations appropriate to each kind of material were given. Contrary to the assertion of Katz, Kampik found that a fatigue effect, manifested in diminished sensitivity to vibration, followed sustained vibratory stimulation.

Anderson (2) reported that sensitivity to vibration and to passive movement decreased with age, and that specific changes in each of these modes of sensibility followed the onset of particular diseases. He expressed the belief that these experiences are relayed over different nervous pathways in the spinal cord, and perhaps in the brain also. Epstein (18), using a tuning fork to excite vibratory sensations, showed that vibratory stimulation is referred to the exact homologous spot on the opposite side of the body. In view of the fact that, in cases of lesions, the length of time taken for these sensations to arise may vary, or sensation be diminished or altogether lacking, vibratory sensation was emphasized as having diagnostic significance.

Von Goetzen (32) determined that relatively few physicians observed that tactual impressions as well as auditory were used in percussion examinations. He found that the limits of the heart and lungs could be determined by percussion as well without hearing as with it. In order to eliminate the influence of knowledge of anatomy he invented and used a "perkussionsphantom," a contrivance in which the position of the object to be localized by percussion could be shifted. Again, tactual impressions were found to be as effective as were auditory. It is von Goetzen's opinion that the diagnostician uses vibratory sensations in percussion examinations but confuses them with auditory experiences.

Pressure and affection and emotions.—In order to test Nafe's contention that affection can be resolved to bright and dull sensations of pressure, Hunt (40) presented a series of colors to trained and naïve subjects, requiring them to report the nature of any pressure sensations which attended the observation of each color. One week later, the same colors were presented with the instruction to report in regard to the pleasantness or unpleasantness of each color. Computation of correlation coefficients resulted in the revelation of a significant relationship between affection and bright and dull pressures. This may be interpreted as indicating either that affection is bright and dull pressure, as Nafe asserts, or that affection is accompanied by bright and dull pressures, which is the view to which Hunt subscribed. In another study, Hunt (39) presented pleasant and

unpleasant emotional situations, demanding that his subjects report if experiences of bright or dull pressure attended the observations. Thirty-six of the fifty-nine introspective reports included references to bright or dull pressure, bright pressure accompanying pleasant and dull pressure unpleasant emotional stimulation. Comparing these results with those of his earlier study, Hunt reached the conclusion that the pleasantness in an emotion was no more intense than that in simple affection, but that the unpleasantness in the emotion was much stronger than that in the affection.

Protopathic and epicritic sensibility.—Stopford (65) defended Head's theory as against the contentions of Trotter and Davies, Boring and Shafer. He undertook to establish that the qualities of protopathic sensibility are integrated at the level of the thalamus, while those of epicritic sensibility have their neurological basis in the cortex. D'Antona (13) related protopathic sensibility primarily to sympathetic, and epicritic to cerebrospinal pathways. Normally both systems operate together, but in certain pathological conditions the epicritic factor is disengaged, allowing the protopathic to manifest its distinctive characteristics. Piéron (53) advanced the view that impulses arising from stimulation by burning are transmitted over delicate, more or less unmyelinated nerve fibers, those for stimulation by pricking over larger, medullated fibers. Owing to the fact that each has a different reaction time, burning is classed with protopathic and pricking with epicritic sensibility.

Autonomic nervous system.—Believing that the autonomic nervous system had an important functional relationship with cutaneous sensibility, Dusser de Barenne (17) performed experiments on animals to determine the influence of sympathectomy upon dermal sensitivity. Removal of the sympathetic chain on one side resulted in homolateral disturbances but did not affect sensitivity on the opposite side. The same conclusion was supported by clinical evidence.

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